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O. V. Kravchenko, assistant professor (BSTU)

ACCURACY INVESTIGATION OF AUTONOMOUS AND RELATIVE METHODS FOR GPS COORDINATE SETTING UNDER FOREST STAND CANOPY

The article considers the application of autonomous and relative methods of GPS coordinates setting under the canopy of trees. The results of accuracy of coordinates determining of points by receivers of navigation and geodetic accuracy classes to create points of geodetic control network on the lands of forest fund, to assess the boundaries of forest land, to control aerial photography, to update cartographic information for GIS. The author makes proposals for improving the accuracy and reliability of GPS measurement results.

Introduction. Geodetic measurement methods using GPS-equipment for forest management and forest inventory has significant advantages over traditional ones.

Such methods make it possible to automate the process of collection and navigation control of forest measurements, to exclude necessity of direct visibility between points, to allow making observations in any weather, both day and night, and so on.

However, the use of GPS-equipment when working under the canopy stand has its own characteristics that impede the passage of signals from the satellites to the GPS-receiver, which affects the positioning accuracy.

The purpose of research is to analyze the accuracy of the results of autonomous and relative methods for GPS coordinate settings with the possibility of further use of the data obtained to create points of geodetic network on the lands of forest fund, to assess the boundaries of forest land, to control aerial photography, to update cartographic information for GIS.

Main part. Field measurements are fulfilled on the site of Negoreloe experimental forestry by navigation receivers GPS Etrex, GPSmap 60C by Garmin and single-frequency receivers of survey-grade Trimble R3.

Geodetic coordinates of points under tree crowns in standard mode and connecting function of receiving signals from satellites EGNOS have been detected by navigation receivers. As a result, the field definitions coordinates of the reference points in the geocentric system WGS-84 were obtained.

To assess the accuracy of the results of autonomous determination there have been made some conversions from geocentric coordinates into local coordinate system being used on the territory of forestry.

Having compared the coordinates of starting points with the results of measurements, there have been calculated coordinate orientation errors by the formulas:

$$m_x = X_{\text{meas}} - X_{\text{true}};$$
$$m_y = Y_{\text{meas}} - Y_{\text{true}},$$

where m_x, m_y – errors in determining the position of the point; X_{meas}, Y_{meas} – coordinates measured by navigation receivers; X_{true}, Y_{true} – the true coordinates of points.

RMS error in location point is calculated by the formula:

$$M_{x,y} = \sqrt{m_x^2 + m_y^2}.$$

The evaluation r of accuracy results are shown in Table.

Having analyzed the data table, it is possible to cay confidently that the use of EGNOS signals does not improve but even worsen coordinates accuracy.

This can be explained by the absence of network base stations on the territory of our republic and Russia, which could correctly and accurately calculate the ionospheric delay and retranslate them to the users through geostationary satellites.

Investigation results indicate that the accuracy of coordinates determining of control points by navigation receiver is in the range of 10–12 m.

In the surface plan that it is sufficient to perform map control of aerial photography of forest resources. These figures are corresponded to the data given in [1, 2].

If we use the existing plans or maps to perform map control of aerial photography, it should be taken into account that the average error of position of points and contours on these maps and plans comprise usually 0.75 mm in the map scale [1].

Results of accuracy assessment of navigational determinations, m

Measurement modes	Receiver Garmin GPSmap 60C			Receiver Garmin GPS Etrex		
	m_x	m_y	$M_{x,y}$	m_x	m_y	$M_{x,y}$
Standard mode	6.45	7.61	9.98	6.85	9.94	12.08
Downlinks from EGNOS	7.88	8.46	11.56	9.11	10.41	13.84

For example, the accuracy of contours on a topographic map with the scale of 1:50 000 corresponds to the real distance of 30 to 40 m, and using GPS-receiver will provide accuracy within 10–12 m. When using single-frequency receivers of survey-grade Trimble R3 «fast static» mode the accuracy of coordinate determining for basic points can comprise about 0.15 cm in the plan [3–6].

Kinematic mode «stop & go» allows to get the coordinates of points under the canopy of the tree stand with an error in plan about 1.2 m.

Kinematic mode «on the fly» allows you to perform quickly field measurements in comparison with the traditional terrestrial geodetic survey (traverse survey or compass method).

However, its significant disadvantage when measured on the amount of forested land is the permanent loss of the signals from the satellites and the time required to re-initialize it.

Therefore, to improve the reliability of the results of measurements it is better to use the combined method of forest areas shooting when the boundary of allotment is determined in a «on the fly» mode with points in «stop & go» mode are coordinated in several places of movement trajectory of the receiver. This technique allows you to initialize periodically the receiver on the ground and thus improves positioning accuracy at low cost time. As a result, the accuracy of the forest areas determining in the plan by means of kinematic mode ranges from 1.4 to 2 m.

The highest accuracy in determining the position is reached in pine stands (1.30–1.36 m). Approximately being equal in accuracy the results of coordination in spruce and birch stands (1.55 and 1.62 m respectively). The lowest accuracy in areas determining is obtained in alder stands (about 2 m).

Conclusion. When working with receivers of navigation class and in order to obtain the accuracy higher than 10–12 m it is necessary to conduct the selection of appropriate locations for basic points, and if possible, to perform vegetation cutting of these places. When working with single frequency GPS-receivers and to improve the accuracy and reliability of survey information, it is necessary to undertake the following activities at the planning step of the satellite measurements:

– to receive almanac including satellite data, their position, time and location, ascending time and residence time within given territory;

– to determine the best "windows" for the satellite measurements.

When conducting field measurements:

– number of satellites must be at least 6 pieces above each defined point;

– to make redundant measurements;

– to increase the residence time in the point (number of measurement epochs) for kinematic modes («stop & go», «on the fly») in 5–6 times compared with that being set in the receiver by default;

– before performing field measurements it is recommended to create your own style of shooting in the receiver;

– when operating in kinematic mode «on the fly» under the canopy of the stand it is necessary to coordinate points in «stop & go» mode in some places of trajectory movement.

At the stage of post-processing results in laboratory it is necessary:

– to analyze the data from satellites;

– to exclude those periods of time when GDSs-signal was weak thus improving accuracy of coordinate setting in 4–5 times.

Investigation data show that the satellite navigation system can be used for the following practical tasks in forestry and forest inventory:

– withdrawal of principle timber cutting areas;

– allotment of forest funds;

– photo point control for composing forest inventory graphic maps.

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